

Headquarters U.S. Air Force

Integrity - Service - Excellence

Permeable Reactive Treatment Biowall



U.S. AIR FORCE

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Introduction

- Field conditions under which chlorinated solvents biodegrade have been studied extensively
 - Methods to verify that biodegradation is occurring exist
 - Conditions conducive to biodegradation occur naturally
 - Can we recreate these conditions?
Yes, ... I think
-



Biodegradation

- Chlorinated solvents:
 - PCE; TCE...DCE...VC
 - Electron donor
 - Carbon, energy source
 - High dissolved organic carbon
- Reducing geochemical conditions
 - Low O₂; nitrate; sulfate; redox
 - High dissolved iron; CO₂; methane



Design Concepts

- Place a slow release organic substrate in intimate contact with contaminated media
 - Permeable reactive treatment wall
 - Dissolved phase containment
 - Requires “fast” ground water velocity
 - Mixing throughout source zone
- Surface Amendment



Design Basis (cont)

- Create a reactive zone of sufficient retention time to achieve desired level of removal
- Substrate must:
 - Support reductive dechlorination through mineralization
 - Be inexpensive enough to emplace a large quantity (<\$1/lb)
 - Last (e.g. >5 years)
 - Be amenable to subsurface distribution and be “permeable”



Bark Mulch

- Supports reductive dechlorination through mineralization ✓?
- Inexpensive enough to emplace a large quantity (<\$1/lb) ✓
- Last (e.g. >5 years) ✓?
- Amenable to subsurface distribution and “permeable” ✓?



Objectives

- Determine if an expensive, readily available source of natural organic carbon can sustain reductive dechlorination
- Document field-scale cost, performance, and end-products



Site Description

- Offutt AFB; Omaha, NE
- Ground water 6 ft. bgs (MW-9S)
- Average hydraulic conductivity - 3.5 ft/day
- Hydraulic gradient - 0.01 ft/ft
- Estimated ground water seepage velocity - 124 ft/year
- DCE; TCE; ... PCE;...VC



Contaminant Profiles

- Tetrachlorethene (PCE) - <2 ug/L
- Trichloroethene (TCE) - < 370 ug/L
- Cis-Dichloroethene (cis-DCE) - <1,200 ug/L
- Trans-DCE - <30 ug/L
- Vinyl chloride - <3 ug/L
- Ethene - Non-detect (ND<1 ug/L)



Geochemical Profile

- Dissolved oxygen - 1 - 3 mg/L
- Nitrate - ~5 mg/L
- Ferrous iron - <0.02 mg/L
- Sulfate - ~40 mg/L
- Methane - ~3 - 20 ug/L
- Hydrogen - ~2 nM



Biowall Construction

■ Dimensions:

- 100 ft (W) x 1 ft (T) x 23 ft (D)

■ Composition:

- 50% actively composting shredded tree material
- 50% Sand

■ Emplacement Method

- Continuous trenching/backfill rig





Surface Amendment Plot

■ Dimensions:

- 30 ft (L) x 15 ft (W) x 1.5 ft (T)

■ Composition:

- 50% actively composting shredded tree material
- 50% Sand

■ Emplacement Method

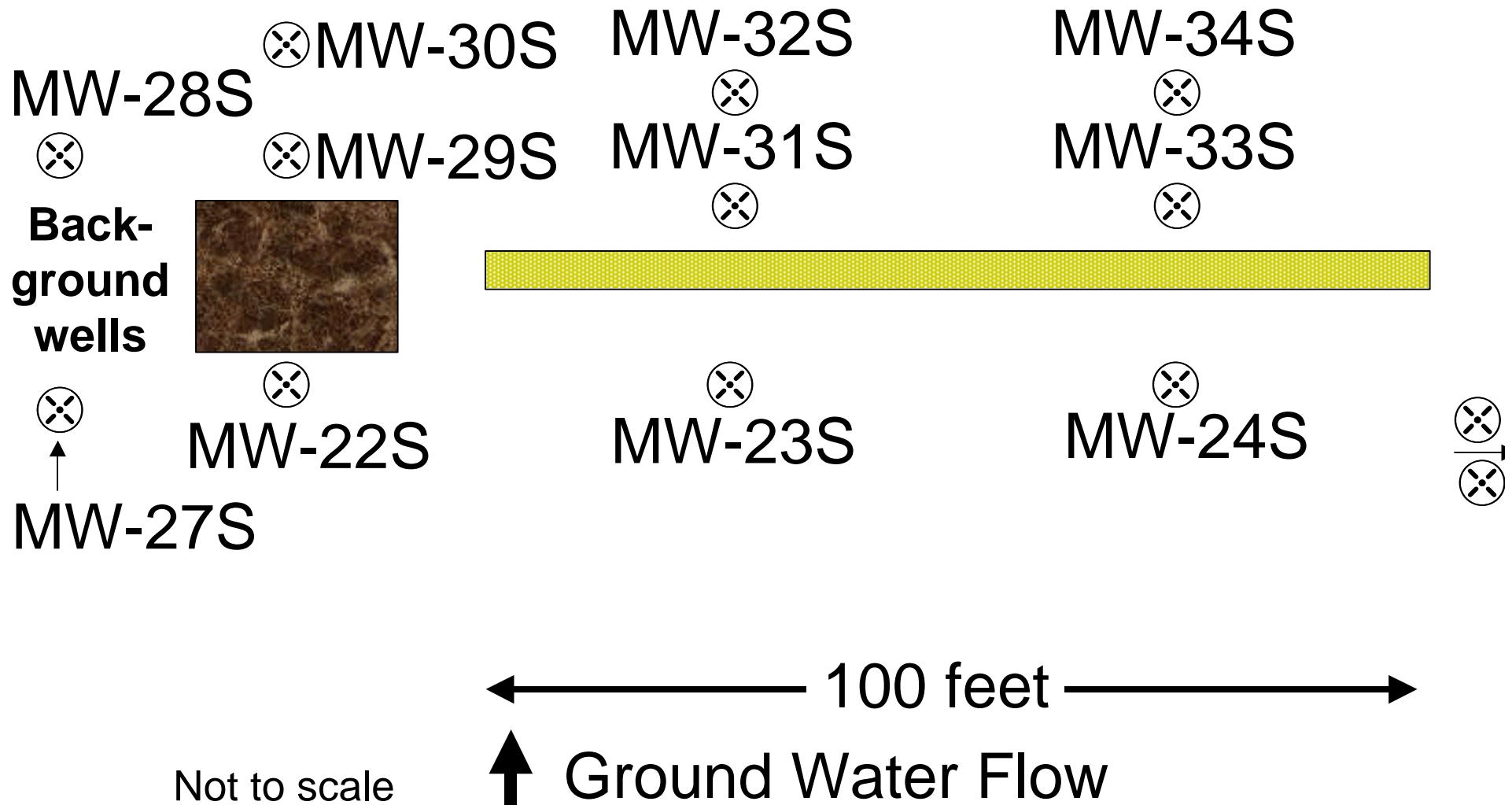
- Backhoe



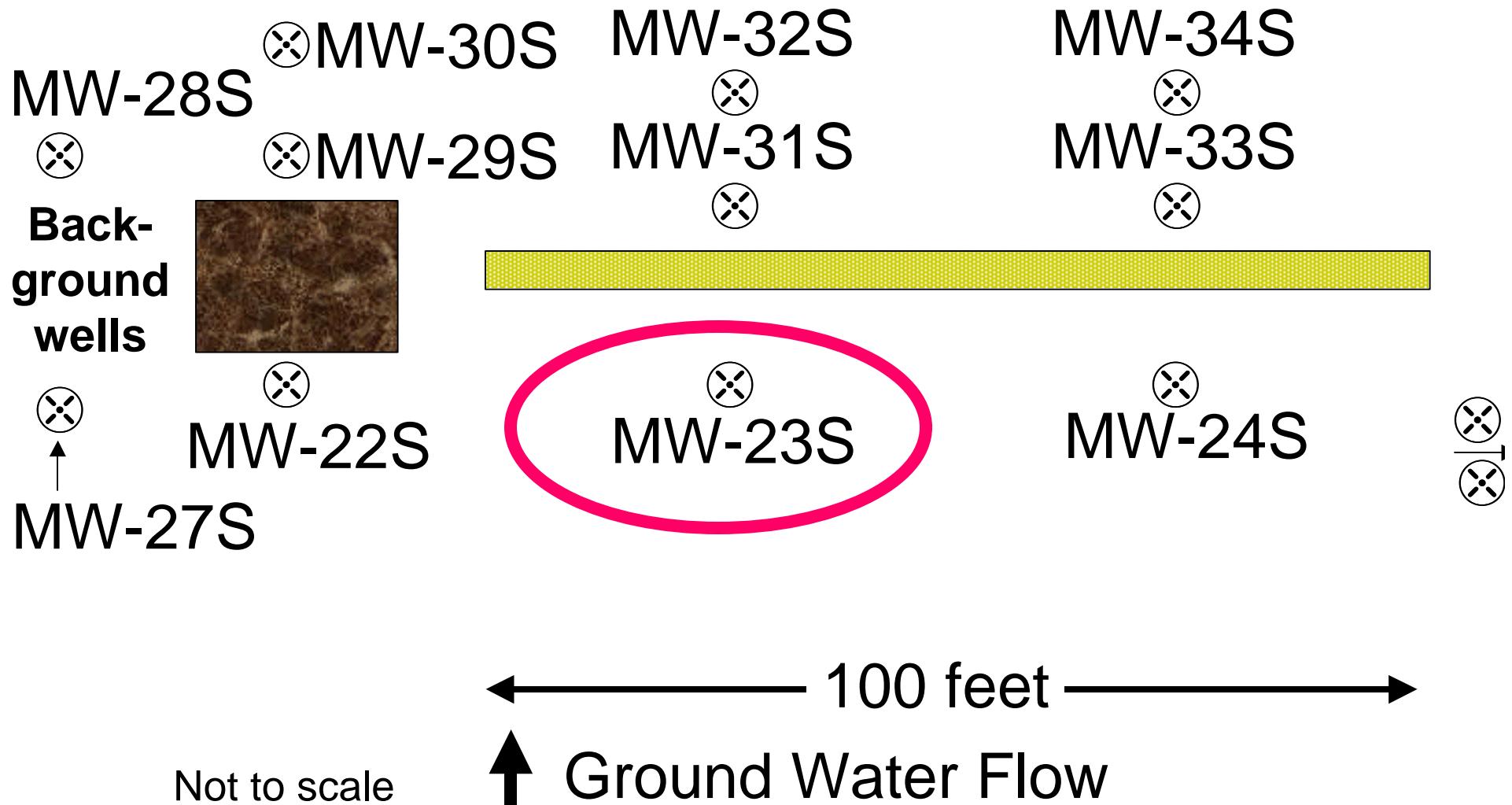
Monitoring Network

- 3 well locations 15 ft upgradient
 - 2 for biowall
 - 1 for surface amendment plot
- 3 well locations 5 ft downgradient
 - 2 for biowall
 - 1 for surface amemdment plot
- 3 well locations 15 ft downgradient
 - Same as above

Surface Amendment Continuous Trench Plot



Surface Amendment Continuous Trench Plot

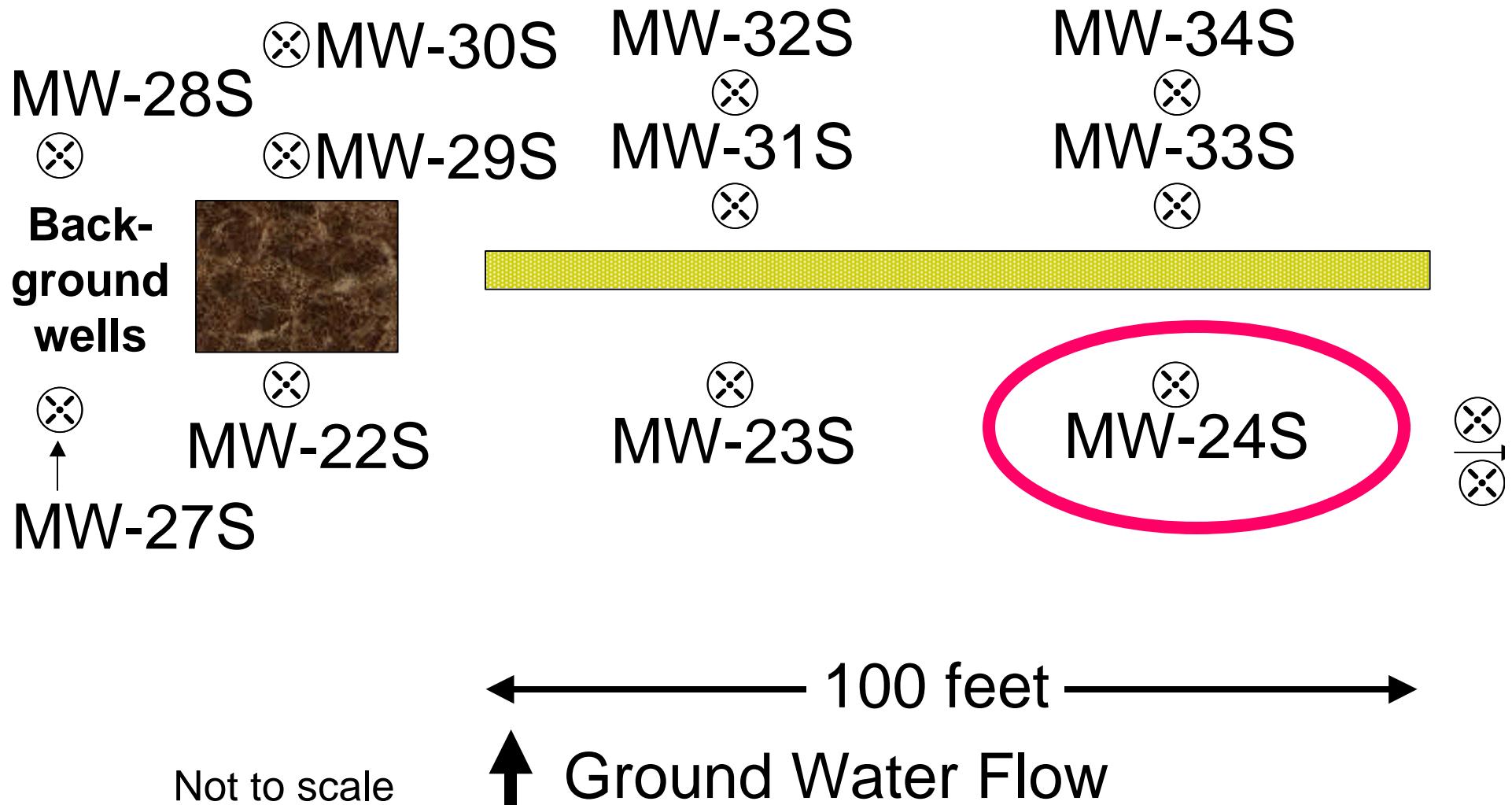




Time Series

	Units	UPGRADIENT MONITORING WELLS		
		Jan. 99 B301-MW23S (B301-2)	Jun. 99 B301-MW23S (B301-2)	Feb-00 B301-MW23S (B301-2)
Chlorinated Organics and Reduction By-Products				
PCE	mg/L	<0.001	<0.001	0.0011
TCE	mg/L	0.670	0.280	1.2
1,1-DCE	mg/L	0.0064	<0.001	0.0047
cis-1,2-DCE	mg/L	0.0082	0.0067	0.0078
trans-1,2-DCE	mg/L	0.0016	0.0011	0.0027
Vinyl chloride	mg/L	<0.001	<0.001	<0.001
Ethene	ng/L	<3200	15	24.0
Ethane	ng/L	<2500	<5	16.0
cDCE/TCE ratio		0.012	0.024	0.01

Surface Amendment Continuous Trench Plot

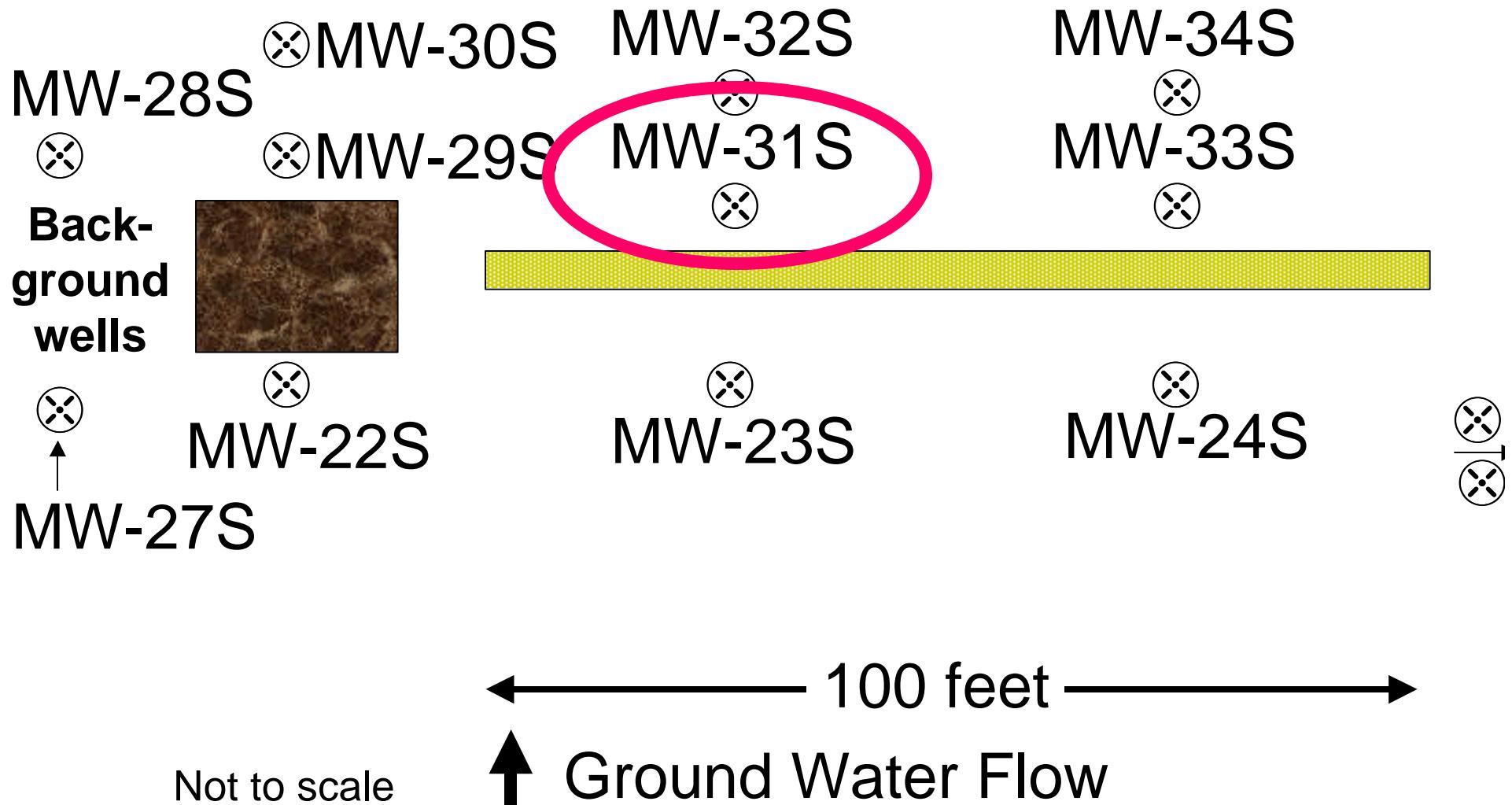




Time Series

Units	UPGRADIENT MONITORING WELLS			
	Jan. 99	Jun. 99	Feb-00	
	B301-MW24S (B301-3)	B301-MW24S (B301-3)	B301-MW24S (B301-3)	
Chlorinated Organics and Reduction By-Products				
PCE	mg/L	<0.001	<0.001	0.0012
TCE	mg/L	1.900	0.250	2.0
1,1-DCE	mg/L	0.003	<0.001	0.0032
cis-1,2-DCE	mg/L	0.020	0.0068	0.014
trans-1,2-DCE	mg/L	0.0041	0.001	0.0039
Vinyl chloride	mg/L	<0.001	<0.001	<0.001
Ethene	ng/L	<3200 ⁴	11	14.0
Ethane	ng/L	<2500 ⁴	<5	8.0
cDCE/TCE ratio		0.011	0.027	0.01

Surface Amendment Continuous Trench Plot

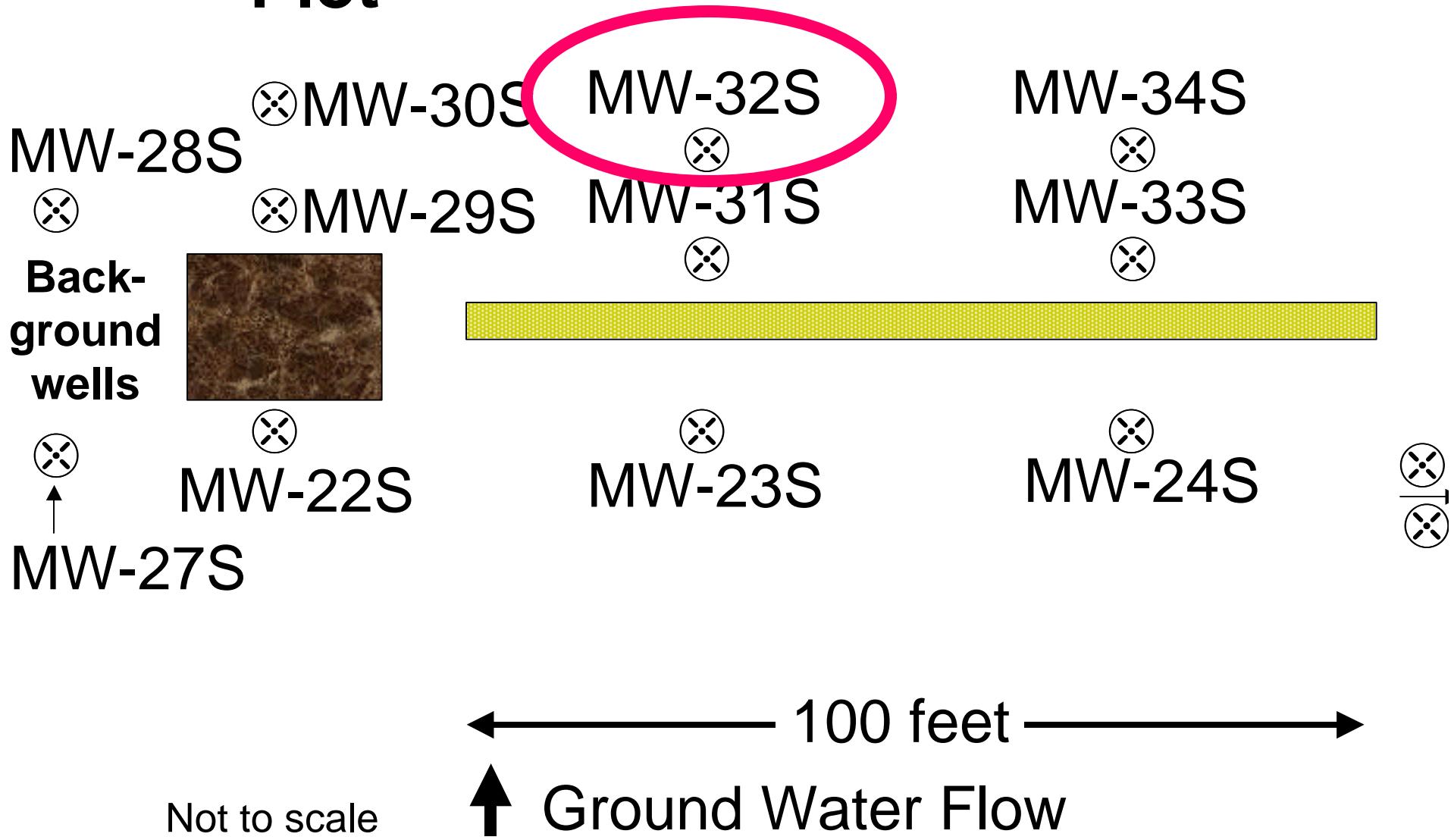




Time Series

DOWNGRADIENT MONITORING WELL		Jan. 99 B301-MW31S (B301-10)	Jun-99 B301-MW31S (B301-10)	Feb-00 B301-MW31S (B301-10)
	Units			
Chlorinated Organics and Reduction By-Products				
PCE	mg/L	<0.001	<0.001	<0.001
TCE	mg/L	0.280	0.013	0.014
1,1-DCE	mg/L	0.0032	0.0012	<0.001
cis-1,2-DCE	mg/L	0.27	0.550	0.0063
trans-1,2-DCE	mg/L	0.0083	0.0045	0.0033
Vinyl chloride	mg/L	0.0023	0.0061	0.002
Ethene	ng/L	<3200	73	1272.0
Ethane	ng/L	<2500	<5	8154
cDCE/TCE ratio		0.964	42.308	0.45

Surface Amendment Continuous Trench Plot

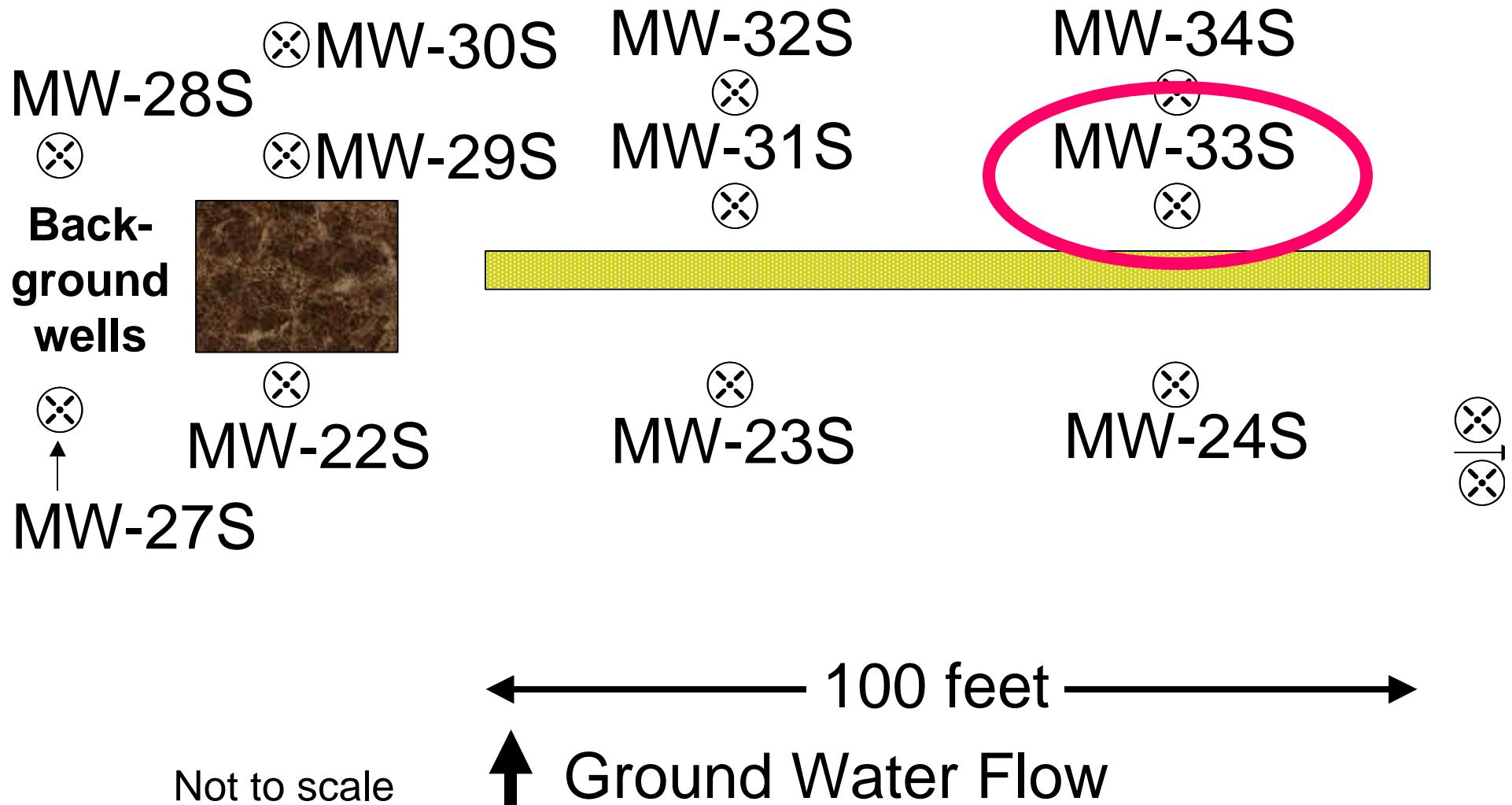




Time Series

Units	DOWNGRADIENT MONITORING WELLS		
	Jan. 99 B301-MW32S (B301-11)	Jun-99 B301-MW32S (B301-11)	Feb-00 B301-MW32S (B301-11)
	Chlorinated Organics and Reduction By-Products		
PCE	mg/L	<0.001	<0.001
TCE	mg/L	0.670	0.130
1,1-DCE	mg/L	0.0024	0.0026
cis-1,2-DCE	mg/L	0.07	0.73
trans-1,2-DCE	mg/L	0.0068	0.0064
Vinyl chloride	mg/L	0.0013	0.0041
Ethene	ng/L	<3200 ⁴	166
Ethane	ng/L	<2500 ⁴	<5
cDCE/TCE ratio		0.104	5.615
			1.73

Surface Amendment Continuous Trench Plot



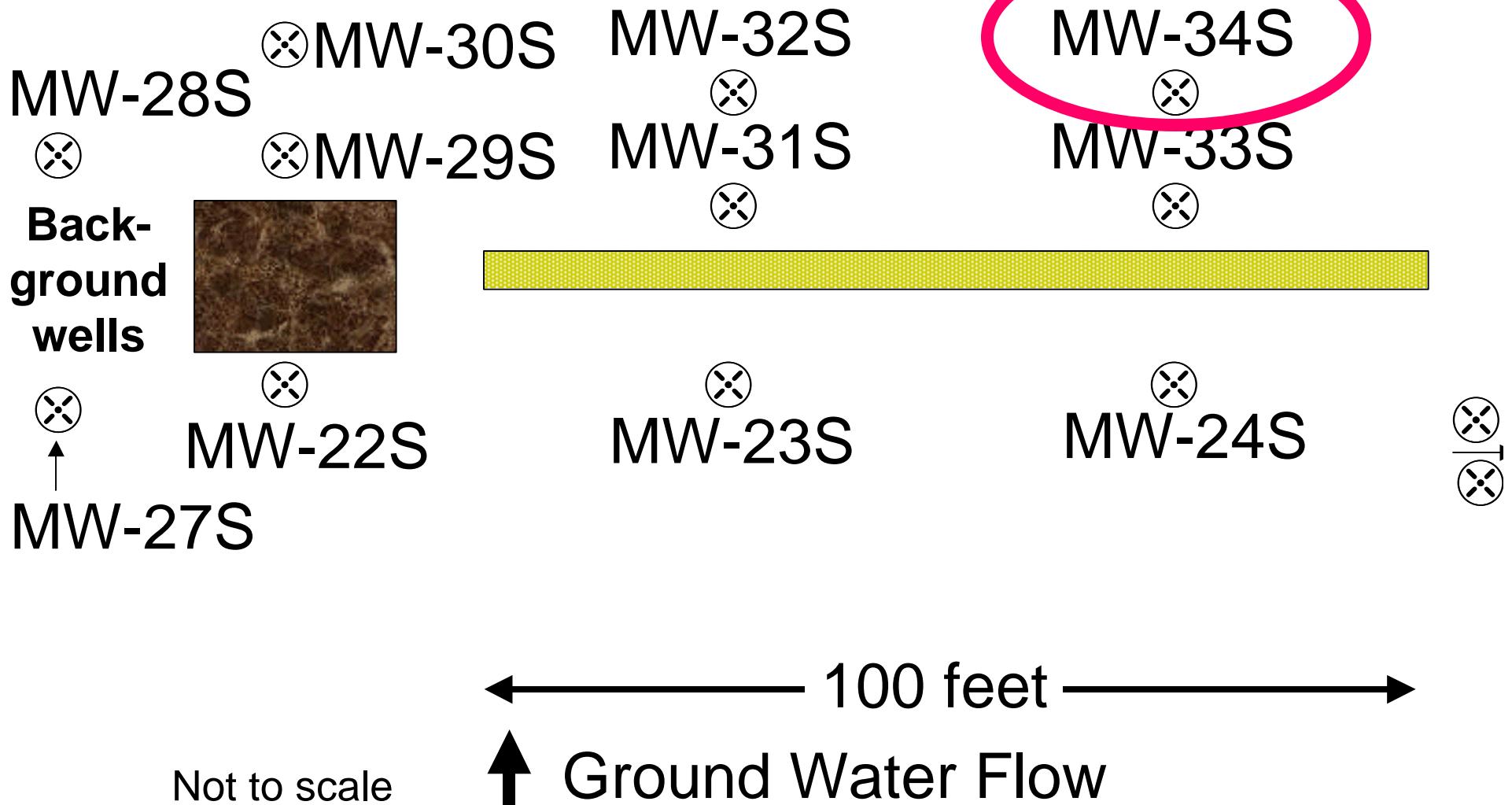


Time Series

Units	DOWNGRADIENT MONITORING WELLS			
	Jan. 99 B301-MW33S (B301-12)	Jun-99 B301-MW33S (B301-12)	Feb-00 B301-MW33S (B301-12)	
Chlorinated Organics and Reduction By-Products				
PCE	mg/L	<0.001	<0.001	<0.001
TCE	mg/L	1.300	0.870	0.215
1,1-DCE	mg/L	0.0023	<0.001	<0.001
cis-1,2-DCE	mg/L	0.045	0.067	0.091
trans-1,2-DCE	mg/L	0.0041	0.0033	0.0055
Vinyl chloride	mg/L	<0.001	<0.001	0.00315
Ethene	ng/L	<3200 ⁴	34	8202.5
Ethane	ng/L	<2500 ⁴	5	22698.5
cDCE/TCE ratio		0.035	0.077	0.425



Surface Amendment Continuous Trench Plot





Time Series

Units	DOWNGRADIENT MONITORING WELLS		
	Jan. 99 B301-MW34S (B301-13)	Jun-99 B301-MW34S (B301-13)	Feb-00 B301-MW34S (B301-13)
	Chlorinated Organics and Reduction By-Products		
PCE	mg/L	<0.001	<0.001
TCE	mg/L	1.300	0.600
1,1-DCE	mg/L	0.0023	<0.001
cis-1,2-DCE	mg/L	0.02	0.040
trans-1,2-DCE	mg/L	0.0027	0.0022
Vinyl chloride	mg/L	<0.001	<0.001
Ethene	ng/L	<3200 ⁴	26
Ethane	ng/L	<2500 ⁴	<5
cDCE/TCE ratio		0.015	0.067
			0.075

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Downgradient Observations

- Progression toward more reducing conditions
 - Lower dissolved oxygen
 - Lower redox potential
 - Reduction in sulfate concentrations
 - Reductions in nitrate concentrations
 - No apparent change in ferrous iron
 - Increase in dissolved methane



cis-DCE:TCE Ratios

■ Biowall - 6 months:

- Upgradient: 0.026 (Mean)
- Downgradient: 12 (Mean)
- Relative change: 470

■ Surface amendment - 6 months:

- Upgradient: 0.024 (Mean)
- Downgradient: 0.35 (Mean)
- Relative change: 15



cis-DCE:TCE Ratios

- Biowall - 12+ months:
 - Upgradient: 0.01 (Mean)
 - Downgradient: 0.67 (Mean)
 - Relative change: 67
- Surface amendment - 12+ months:
 - Upgradient: 0.01
 - Downgradient: 0.21 (Mean)
 - Relative change: 21



Summary

- Objective - mimic Mother Nature (i.e. create a Type 2 site)
- Lines of evidence support enhanced biodegradation effect
- 90% TCE reduction after 1 year
- Bark Mulch supports reductive dechlorination
- Improving over time



Summary (cont)

- Ethene/Ethane Production up 2 - 3 orders of magnitude
- Sampling of trench material does not indicate significant sorption
- Surface Amendment Plot
 - Extremely simple installation
 - Surprised to see apparent effect due to clayey soils and 6 ft depth to GW